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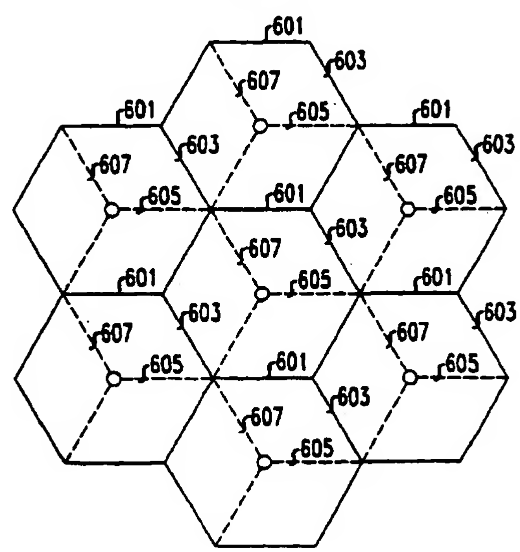
(54) Frequency hopping multicarrier transmission in segmented cells

(57) A base station within a cell of an orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access system employs sectorization as a way to reduce the intercell interference. The cell is sectorized from a transmission point of view by the directionality of the downlink antenna, and the OFDM tone set employed in each cell is correspondingly sectorized, i.e., each sector in the cell is allocated a set of tones within a sub-band of the available frequency bandwidth for use when transmitting into that sector. The sub-bands assigned to each sector are periodically changed, or "hopped", among the available sub-bands within the totally available bandwidth. Such sub-band hopping is a so-called "slow" hopping, in that it is not performed on a symbol-by-symbol basis but instead occurs only after more than one symbol has been transmitted in a sector on tones within the sub-band. Each sector employs its own pilot signal, which is assigned one or more tones within the sub-band currently employed by that sector. Similarly, for the uplink, the base station may employ a directional receiver antenna. Preferably, the mobile terminal only transmits on a tone that is within a sub-band that is allocated to the sector in which the mobile terminal is located. This, sub-band, however, need not correspond to the same location within the bandwidth as the sub-band used by the downlink to communicate with the mobile terminal.

FIG. 6



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Description

Technical Field

[0001] This invention relates orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access such as may be used in wireless, and other, communication systems.

Background of the Invention

[0002] It is desired that wireless communication systems be as efficient as possible to maximize a) the number of users that can be served and b) the data rates, if data service is provided. Wireless systems are shared media systems, i.e., there is a fixed available bandwidth that must be shared among all the users of the system. These systems are often implemented as so-called "cellular" systems, where the covered territory is divided into separate cells, and each cell is served by a base station.

[0003] It is well known in the art that the two particularly desirable features of a cellular wireless system are 1) that the intracell interference, i.e., interference experienced by one user that is caused by other users that are within the same cell as that user, be as small as possible, and 2) that the intercell interference, i.e., interference experienced by one user that is caused by other users that are in cells other than the one in which the user is located, is avenged across all users in neighboring cells. Most prior art digital cellular systems are time division multiple access (TDMA) systems, such as group special mobile (GSM)-, intermediate standard (IS)-136-, or IS-54-based systems, or they are code division multiple access (CDMA) systems, e.g., IS-95 based systems.

[0004] In prior art narrow band TDMA systems neighboring base stations use different, e.g., non-overlapping, parts of the available spectrum. However, bases stations that are sufficiently far away from each other to avoid substantial interference between them, i.e., non-neighboring base stations, may use the same parts of the available spectrum. Notwithstanding such spectrum reuse, the spectrum available for use in each cell is a small part of the total available spectrum. Each user in a cell has its own unique frequency band and time slot combination, and hence TDMA systems have no intracell interference, i.e., they have the first desirable feature of cellular wireless systems. However, TDMA systems do not have the second desirable feature, in that a given user only interferes with a small number of users outside the cell, so that spectral reuse is based on worst case interference rather than average interference. As a result, the system has a low "spectral" efficiency.

[0005] In prior art direct sequence (DS)-CDMA systems the entire bandwidth is used by each base station but each base station uses a different spreading code. Such CDMA systems promise higher spectral efficiency than narrow band TDMA systems. Thus, CDMA systems have the second desirable feature of a cellular wireless system. However, CDMA systems do not have the first desirable feature of a cellular wireless system because although the signals transmitted from the base station within a cell are orthogonal, because of channel dispersion, the signals received at a receiver are not necessarily orthogonal. This results in interference between users within the same cell.

[0006] Proposed prior art frequency hopping (FH)-CDMA systems are very similar to narrow band TDMA systems, except that they employ frequency hopping to also obtain the second desirable feature of a cellular wireless system. In particular, each transmitter transmits a narrow band signal, and periodically changes the carrier frequency to achieve the frequency hopping. However, disadvantageously, such hopping is relatively slow, reducing the amount of averaging that can be achieved for a given delay in the transmission path that the system can tolerate.

[0007] United States Patent No. 5,410,538 issued to Roche et al. on April 25, 1995 discloses a multi-tone CDMA system. Such a system is essentially an OFDM system that eliminates intracell interference by insuring that the received signals within a cell are orthogonal. Thus, the Roche et al. system has both desirable features of a cellular wireless system. However, the Roche et al. system partitions the spectrum into a large number of tones, which makes the system very susceptible to Doppler shifts in mobile systems. Also, because each mobile user transmits on a large number of tones, the peak-to-average ratio of the mobile transmitter is very high, resulting in poor power efficiency at the mobile station, which is disadvantageous in that power is often a limited resource in the mobile station.

[0008] United States Patent No. 5,548,582 issued to Brajal et al. on August 20, 1996 discloses a general wide-band orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access.

[0009] We have recognized in United States Patent Application Serial No. (Case Laroia 9-1-1) that the Brajal et at. system is not optimized for use in a cellular system in that there is no teaching therein how to optimize a) the hopping pattern, b) the tone assignment, or c) the bandwidth reuse. We have further recognized that optimizing these factors, individually and/or collectively, is important to obtain a spectrally efficient system, i.e., a system that has the two particularly desirable features of a cellular wireless system. In particular, we disclosed in United States Patent Application Serial No. (Case Laroia 9-1-1) dividing the entire bandwidth into orthogonal tones, and reusing all of the orthogonal tones in each cell. To reduce peak-to-average ratio at the mobile transmitter, low bit rate user, such as a voice user, is allocated preferably a single one, but no more than a very small number, of the orthogonal tones for use in communicating with the base station. Data users are

similarly allocated tones for data communication. However, the number of tones assigned for each data particular user is a function of the data rate for that user. The tone assignment for a given user is not always the same within the available band, but instead the tones assigned to each user are hopped over time.

[0010] A tone hopping pattern was disclosed that achieves maximum frequency diversity and averages the intercell interference, e.g., using a pattern that is a function of a mutually orthogonal latin square. More specifically, in the downlink, i.e., in the channel from the base station to the mobile station, the tones assigned to each user are change relatively rapidly, e.g., from symbol to symbol, i.e., the user fast "hops" from one tone to another. However, in the uplink, i.e., in the channel from the mobile station to the base station, although fast hopping is possible, preferably slow hopping is employed to allow efficient modulation of the uplink signal. However, when slow hopping is used in the uplink, it is necessary to employ additional techniques, such as interleaving, to compensate for the reduction in the intercell interference averaging effect.

Summary of the Invention

[0011] We have recognized that notwithstanding the foregoing advancements, additional improvements are yet necessary to achieve a spectrally efficient system, i.e., a system that has the two particularly desirable features of a cellular wireless system. One such improvement, in accordance with the principles of the invention, is the use by a base station within a cell of a directional antenna in order to be able to employ sectorization as a way to reduce the intercell interference. In accordance with an aspect of the invention, not only is the cell sectorized from a transmission point of view by the directionality of the downlink antenna, but the OFDM tone set employed in each cell is correspondingly sectorized, i.e., each sector in the cell is allocated a set of tones within a sub-band of the available frequency bandwidth for use when transmitting into that sector. For example, with hexagonally shaped cells, all the sectors with the same directional orientation are allocated tones within the same sub-band.

[0012] In accordance with another aspect of the invention, the sub-bands assigned to each sector are periodically changed, or "hopped", among the available sub-bands within the totally available bandwidth. Such sub-band hopping is a so-called "slow" hopping, in that it is not performed on a symbol-by-symbol basis but instead occurs only after more than one symbol has been transmitted in a sector on tones within the sub-band. Furthermore, the slow hopping of the sub-bands can be no faster than slow hopping which may be employed in the uplink, i.e., the link from the mobile terminal to the base station, such as is described in United States Patent Application Serial No. (Case Laroia 9-1-1). In the downlink, each sector employs its own pilot signal, which is assigned one or more tones within the sub-band currently employed by that sector.

[0013] Similarly, for the uplink, the base station may employ a directional receiver antenna. Preferably, in accordance with an aspect of the invention, the mobile terminal only transmits on a tone that is within a sub-band that is allocated to the sector in which the mobile terminal is located. This, sub-band, however, need not correspond to the same location within the bandwidth as the sub-band used by the downlink to communicate with the mobile terminal.

Brief Description of the Drawing

[0014] In the drawing:

FIG. 1 shows an example of available orthogonal tones at one cell with a spacing of Δ, within a bandwidth W;

FIG. 2 shows a time domain view of the symbol period which is available for symbol transmission, and the additional time required for transmission of the cyclic prefix;

FIG. 3 shows a block diagram of an exemplary OFDM transmitter;

FIG. 4 shows a block diagram of an exemplary OFDM receiver;

FIG. 5 shows further details of an exemplary implementation of data-to-tone applier of FIG. 3 for a base station;

FIG. 6 shows several contiguous hexagonally shaped cells;

FIG. 7 shows one allocation of sub-band assignment for sets of the hexagonally shaped sectors of FIG. 6;

FIG. 8 shows another allocation of sub-band assignment for sets of the hexagonally shaped sectors of FIG. 6; and

FIG. 9 shows an exemplary hopping pattern from one user, in accordance with the principles of the invention.

Detailed Description

[0015] The following merely illustrates the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements which, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples and conditional language recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and

embodiments of the invention, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure.

[0016] Thus, for example, it will be appreciated by those skilled in the art that the block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudocode, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

[0017] The functions of the various elements shown in the FIGs., including functional blocks labeled as "processors" may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, read-only memory (ROM) for storing software, random access memory (RAM), and non-volatile storage. Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the FIGS. are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementor as more specifically understood from the context.

[0018] In the claims hereof any element expressed as a means for performing a specified function is intended to encompass any way of performing that function including, for example, a) a combination of circuit elements which performs that function or b) software in any form, including, therefore, firmware, microcode or the like, combined with appropriate circuitry for executing that software to perform the function. The invention as defined by such claims resides in the fact that the functionalities provided by the various recited means are combined and brought together in the manner which the claims call for. Applicant thus regards any means which can provide those functionalities as equivalent as those shown herein.

[0019] Before describing the invention it is necessary to understand generally the environment in which the invention operates, namely, orthogonal frequency division multiplexing (OFDM) systems.

[0020] Orthogonal frequency division multiplexing (OFDM) systems employ orthogonal tones within a frequency bandwidth to transmit data from different users at the same time. In particular, for any particular symbol period T which is available for symbol transmission, and a given bandwidth W, the number of available orthogonal tones N, is given by WT. In accordance with an aspect of the invention, the same bandwidth W is reused in each cell. The spacing between the orthogonal tones is Δ, which is given by 1/T. In addition to the symbol period T which is available for symbol transmission, an additional time Tc is required for transmission of a cyclic prefix, which is prepended to each symbol period and is used to compensate for the dispersion introduced by the channel response and the pulse shaping filter used at the transmitter. Thus, although a total period of T+Tc is employed, only T is available for user data transmission.

[0021] FIG. 1 shows an example of available orthogonal tones at one cell with a spacing of Δ within a bandwidth W. FIG. 2 shows a time domain view of the symbol period T which is available for symbol transmission, and the additional time Tc required for transmission of the cyclic prefix. Note that within each symbol period T data may be sent on each of the tones substantially simultaneously. Also, the last portion of the data symbol period T is often employed as the cyclic prefix in manner shown in FIG. 2.

[0022] FIG. 3 shows a block diagram of exemplary OFDM transmitter 301. Because of its high level, whether or not the diagram of FIG. 3 depicts a prior art OFDM transmitter or an OFDM in accordance with the principles of the invention depends on the particular implementation of the various components of FIG. 3. Also, OFDM transmitter 301 may be used in either a base station as the downlink transmitter or in a mobile station as an uplink transmitter. The particular embodiments necessary for either application will be described more fully hereinbelow.

[0023] OFDM transmitter 301 includes a) encoder 303, b) data-to-tone applier 305, c) tone assignment unit 307, and d) cyclic prefix prepender 309.

[0024] Encoder 303 receives an overall information stream for transmission from a source and encodes it according to a particular encoding scheme. Such overall information stream typically includes information streams generated on behalf of more than one user if OFDM transmitter 301 is being used in a base station and only includes information streams for one user if OFDM transmitter 301 is being used in a mobile station. The encoding scheme employed may vary whether the information being transmitted in a particular information stream is voice or data. Those of ordinary skill in the art will be able to 1) select, e.g., traditional convolutional or block coding, or 2) devise, appropriate encoding schemes as a function of the model of the interference environment in which the OFDM system is being deployed.

[0025] Data-to-tone applier 305 modulates the overall encoded information stream supplied as an output from encoder 303 onto the various available tones. For each particular encoded information stream within the overall encoded information stream at least one tone is assigned by tone assignment unit 307, and that tone is used to modulate the particular encoded information stream received from encoder 303. If a particular encoded information stream is voice then, in accordance with an aspect of the invention, preferably a single one, but no more than a very small number, of the orthogonal tones are assigned for particular encoded information stream. If a particular encoded information stream is data then, in accordance with an aspect of the invention, the number of orthogonal tones assigned that particular encoded information stream is a function of the data rate for the user of that particular encoded information stream.

[0026] Tones are assigned to each encoded information stream by tone assignment unit 307, which conveys the assignments to data-to-tone applier 305. The tone assignment for a given user is not always the same within the available band, but instead the tones assigned to each user are hopped over time by tone assignment unit 307.

[0027] Cyclic prefix prepender 309 adds the cyclic prefix to each symbol period as described above. The cyclic prefix is added only for the tones being used by OFDM transmitter 301. Thus, for example, if OFDM transmitter 301 is in a base station using all of the tones, then the cyclic prefix uses all of the available orthogonal tones within bandwidth W. If OFDM transmitter 301 is in a mobile station using only a single one of the tones, then the cyclic prefix uses only that particular single tone. Advantageously, use of the cyclic prefix eliminates the need for equalization at the receiver.

[0028] FIG. 4 shows a block diagram of an exemplary OFDM receiver 401. As with FIG. 3 because of its high level, whether or not the diagram of FIG. 4 depicts a prior art OFDM receiver or an OFDM in accordance with the principles of the invention depends on the particular implementation of the various components of FIG. 4. Also, as shown OFDM receiver 401 may be used in either a base station as the downlink receiver or in a mobile station as an uplink receiver. The particular embodiments necessary for either application will be described more fully hereinbelow.

[0029] OFDM receiver 401 includes a) cyclic prefix remover 409, b) tone-to-data extractor 405, c) tone assignment unit 407, and d) decoder 403.

[0030] The signal received at OFDM receiver 401, e.g., by an antenna and amplifier arrangement, not shown, is supplied to cyclic prefix remover 409. Cyclic prefix remover 409 removes the cyclic prefix from each total period of the received signal. The remaining signal, with period T, is supplied to tone-to-data extactor 405.

[0031] Tone-to-data extractor 405 extracts each information stream received on the various available tones which are being used by OFDM receiver 401 to develop an overall reconstructed data stream. Tones are assigned for use by OFDM receiver 401 by tone assignment unit 407, which conveys the assignments to data-to-tone remover 405. The tone assignment for a given user is not always the same within the available band, but instead the tones assigned to each user are hopped over time by tone assignment unit 407. As a result, it is necessary that there be correspondence between tone assignment unit 307 of OFDM transmitter 301 and tone assignment unit 407 of an associated OFDM receiver 401. Such correspondence is typically achieved through à priori arrangement, e.g., upon call set up.

[0032] Decoder 403 receives an overall information stream from transmission tone-to-data extractor 405 and decodes it to develop an overall output information stream. The decoding is often performed according to the inverse of the scheme used to encode the information stream. However, modifications may be made to the decoding scheme to account for channel and other effects to produce a more reliable decoded output than simply using the inverse of the encoding scheme. Alternatively, specific algorithms may be developed for use in decoding the received signal that take into account channel response, interference, and other effects. Such overall output information stream typically includes information streams generated on behalf of more than one user if OFDM receiver 401 is being used in a base station and only includes information streams for one user if OFDM receiver 401 is being used in a mobile station.

[0033] The resulting overall output stream is supplied to a destination for further pocessing. For example, if the information stream is voice and OFDM receiver 401 is within a mobile station, then the information stream is supplied to be converted to an audible signal that is played for the user. If the information stream is voice and OFDM receiver 401 is within a base station, the voice information may be separated for transmission to the ultimate destination, e.g., via a wireline network.

[0034] FIG. 5 shows further details of an exemplary implementation of data-to-tone applier 305 for a base station. Each of multipliers 501 multiplies a particular information stream by a sinusoidal waveform which is one of the orthogonal tones and is generated by tone generator 503. The resulting modulated signals are then summed by adder 505. Typically, data-to-tone applier 305 is implemented digitally, e.g., by a processor performing the functionality of multipliers 501, tone generator 503, and adder 505 using digital representations of the orthogonal tones.

[0035] The same general architecture as shown in FIG. 5 may be used to implement data-to-tone applier 305 for a mobile station. However, instead of covering the entire range of N orthogonal tones used within the cell by the base station by having N multipliers, only the

maximum number of orthogonal tones used by the mobile station need have available multipliers. Since many mobile stations are used strictly for voice, only one multiplier need be provided. However, since, as will be described in more detail hereinbelow, the tone assignments for each user are changed, it is necessary that the tone generator in a mobile station be able to generate the entire range of N orthogonal tones. Furthermore, if only one tone is used, adder 505 may be dispensed with.

[0036] As described above, the tones assigned to any particular information stream is changed periodically. This is known in the art generally as frequency hopping, and is referred to herein more specifically as tone hopping.

[0037] In accordance with the principles of the invention, in OFDM systems, the antenna ultimately transmitting the overall encoded information stream as applied to the various available tones may be a directional antenna so that sectorization of the cell may be employed as a way to reduce the intercell interference. In accordance with an aspect of the invention, not only is the cell sectorized from a transmission point of view by the directionality of the downlink antenna, but the OFDM tone set employed in each cell is correspondingly sectorized, i.e., each sector in the cell is allocated a set of tones within a sub-band of the available frequency bandwidth for use when transmitting into that sector.

[0038] FIG. 6 shows several contiguous hexagonally shaped cells 601. Within hexagonally shaped cells 601 , all sectors with the same directional orientation, e.g., sets of sectors 603, 605 and 607, are allocated tones within the same sub-band, as indicated by labels 1, 2, and 3. FIG. 7 shows one allocation of sub-band assignment for sets of sectors 603, 605, and 607 to sub-bands 1, 2, and 3, respectively. In accordance with another aspect of the invention, the sub-bands assigned to each sector are periodically changed, or "hopped", among the available sub-bands within the totally available bandwidth. Thus, FIG. 8 shows another, e.g., later, allocation of sub-band assignment for sets of sectors 603, 605, and 607 to sub-bands 3, 1, and 2, respectively.

[0039] Such sub-band hopping is preferably a so-called "slow" hopping, in that it is not performed on a symbol-by-symbol basis but instead occurs only after more than one symbol has been transmitted in a sector on tones within the sub-band. Furthermore, the slow hopping of the sub-bands can be no faster than the slow hopping that may be employed in the uplink, i.e., the link from the mobile terminal to the base station, such as is described in United States Patent Application Serial No. (Case Laroia 9-1-1).

[0040] FIG. 9 shows an exemplary hopping pattern for the mobile terminal of one user, in accordance with the principles of the invention. Each column represents a symbol or set of symbols that is transmitted, for a given time period. The length of the time period and the length of the symbol period T determine whether each column represents a single symbol or a set of symbols. However, preferably, in the downlink each column represents a single symbol and in the uplink each column represents a set of symbols. The rows of FIG. 9 represents a tone that is used to transmit the user's symbol or set of symbols. The tones included within sub-bands 1, 2, and 3, are identified on the Y-axis of FIG. 9.

[0041] According to the exemplary hopping pattern of FIG. 9, the user's mobile terminal first experiences several symbol periods, e.g., 5, within sub-band 1 using various tones therein, at which point the sector the user's mobile terminal is located in switches to sub-band 2. The user's mobile terminal then experiences several symbol periods within sub-band 2, at which point the sector the user's mobile terminal is located in switches to sub-band 3. After 3 symbol periods, the user's mobile terminal leaves the sector it was located in and enters another sector of the same cell that is using tones in sub-band 2. The user's mobile terminal thus experiences an additional two symbol periods in sub-band 2, at which point the new sector in which the user's mobile terminal became located in hops to sub-band 3. The user's mobile terminal then experiences 5 symbols in sub-band 3. Finally, the new sector that the user's mobile terminal is located in hops back to sub-band 1, and the user's mobile terminal employs 5 symbols in sub-band 1, whereupon the user turns off his mobile terminal.

[0042] Note that there is no requirement for user to experience each tone in a sub-band before the sub-band employed by the user is changed.

[0043] The sub-bands assigned to the various sectors are preferably, identical in bandwidth, as well as contiguous, continuous, and nonoverlapping in the frequency domain. Note, however that the sub-bands assigned to the various sectors may be overlapping as such an arrangement may be able to achieve higher capacity for the entire system. Additionally, the sub-bands need not have identical bandwidths, so that some sub-bands may include more tones than other sub-bands. Furthermore, the tones making up a sub-band may change dynamically. In fact, the tones making up a sub-band need not be contiguous in the frequency domain. However, the system with contiguous sub bands may require less tones for use as pilot signals.

[0044] A pilot signal is a signal that is known to the receiver, and so the pilot signal as received can be used for purposes such as channel estimation, e.g., by figuring out the operation performed by the channel to the pilot signal as transmitted in order to develop the pilot signal as received. In accordance with an aspect of the invention, each sector employs its own pilot signal, which is assigned one or more tones within the sub-band currently employed by that sector. Thus, for the above example shown in FIGs. 6-8, there would be three pilot signals in the downlink, one within sub-band

1, another within sub-band 2, and a third within sub-band 3. The tones used for the pilot signal are hopped along with all the other tones carrying user information. If more than one tone is employed as the pilot signal, the tones making up the pilot signal may be separated from each other. Such separation may be used to achieve better channel estimation, because, by distributing the tones used by the pilot signal across the sub-bands, the channel effects experienced by the tones of the pilot signal are more likely to be representative of the channel effects experienced by adjacent tones carrying user data.

[0045] Similarly, for the uplink, which is the channels from the mobile terminal to the base station, the base station may employ a directional receiver antenna. Preferably, in accordance with an aspect of the invention, the mobile terminal only transmits on a tone that is within a sub-band that is allocated to the sector in which the mobile terminal is located. This sub-band, however, need not correspond to the same location within the bandwidth as the sub-band used by the downlink to communicate with the mobile terminal.

Claims

1. A method for operating a cellular orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system, employing within a cell of said system a plurality of directional antennas each oriented so as to divide said cell into a plurality of sectors, each of said sectors corresponding to one of said directional antennas, the method comprising the steps of:

    dividing a frequency spectrum available to said OFDM based spread spectrum multiple access wireless system into a plurality of sub-bands;
    assigning a first respective one of each of said sub-bands to each respective one of said sectors;
    assigning at least a first tone for communication to each terminal within each of said sectors, each first tone assigned to each of said terminals being within said first sub-band assigned to the one of said sectors within which said each terminal is located;
    using said assigned first tones to communicate at least one symbol;
    assigning at least a second tone for communication to each terminal within each of said sectors, each second tone assigned to each of said terminals being within said first sub-band assigned to the one of said sectors within which said each terminal is located;
    using said assigned second tones to communicate at least one symbol;
    assigning a second respective one of each of said sub-bands to each respective one of said sectors;
    assigning at least a third tone for communication to each terminal within each of said sectors, each third tone assigned to each of said terminals being within said second sub-band assigned to the one of said sectors within which said each terminal is located.

2. The invention as defined in claim 1 wherein said first tone is used for communication first, subsequently said second tone is used for communication, and yet later than use of said second tone said third tone is used for communication.

3. The invention as defined in claim 1 further comprising the steps of:

    using said assigned third tones to communicate at least one symbol;
    assigning at least a fourth tone for communication to each terminal within each of said sectors, each fourth tone assigned to each of said terminals being within said second sub-band assigned to the one of said sectors within which said each terminal is located.

4. The invention as defined in claim 1 wherein said first sub-band assigned to any particular one of said sectors is different from said second sub-band assigned to said particular one of said sectors.

5. The invention as defined in claim 1 wherein each of said sub-bands is nonoverlapping in the frequency domain with any other of said sub-bands; or is continuous in the frequency domain; or occupies a contiguous spectrum in the frequency domain.

6. The invention as defined in claim 1 wherein each of said sectors employs its own respective pilot signal, each said pilot signal being made up of one or more tones within the one of said sub-bands currently assigned to the one of said sectors employing said pilot signal.

7. The invention as defined in claim 1 wherein each terminal only transmits on a tone that is within said sub-band that is presently assigned to the sector in which said each mobile terminal is located.

8. A method for operating a cellular orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system, employing within a cell of said system a plurality of directional antennas each oriented so as to divide said cell into a plurality of sectors, each of said sectors corresponding to one of said directional antennas, the method comprising the steps of:

dividing the frequency spectrum available to send OFDM based spread spectrum multiple access wireless system into a plurality of sub-bands;

assigning a first respective one of each of said sub-bands to each respective one of said sectors;

assigning at least a first tone for communication to each terminal within each of said sectors, each first tone assigned to each of said terminals being within said first sub-band assigned to the one of said sectors within which said each terminal is located;

using said assigned first tones to communicate a plurality of symbols;

assigning a second respective one of each of said sub-bands to each respective one of said sectors;

assigning at least a second tone for communication to each terminal within each of said sectors, each second tone assigned to each of said terminals being within said second sub-band assigned to the one of said sectors within which said each terminal is located.

9. The invention as defined in claim 8 further comprising the step of:

using said assigned second tones to communicate a plurality of symbols.

10. The invention as defined in claim 1 or 8 wherein at least one of said sub-bands remains unassigned to any sector after each of said assigning steps.

11. Software in a computer readable form for use in a tone assignment unit of a cell of a cellular orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system in which a frequency spectrum available to said OFDM based spread spectrum multiple access wireless system is divided into a plurality of sub-bands, said tone assignment unit including a processor for executing software, said software comprising:

a module for assigning a first respective one of each of said sub-bands to each respective one of said sectors;

a module for assigning at least a first tone for communication to each terminal within each of said sectors, each first tone assigned to each of said terminals being within said first sub-band assigned to the one of said sectors within which said each terminal is located;

a module for assigning a second respective one of each of said sub-bands to each respective one of said sectors after said assigned first tones are used to communicate a plurality of symbols;

a module for assigning at least a second tone for communication to each terminal within each of said sectors, each second tone assigned to each of said terminals being within said second sub-band assigned to the one of said sectors within which said each terminal is located.

12. Software in a computer readable form for use in a tone assignment unit of a cell of a cellular orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system in which a frequency spectrum available to said OFDM based spread spectrum multiple access wireless system is divided into a plurality of sub-bands, said tone assignment unit including a processor for executing software, said software comprising:

a module for assigning a first respective one of each of said sub-bands to each respective one of said sectors;

a module for assigning at least a first tone for communication to each terminal within each of said sectors, each first tone assigned to each of said terminals being within said first sub-band assigned to the one of said sectors within which said each terminal is located;

a module for assigning at least a second tone for communication to each terminal within each of said sectors, each second tone assigned to each of said terminals being within said first sub-band assigned to the one of said sectors within which said each terminal is located after said assigned first tones are used to communicate at least one symbol;

a module for assigning a second respective one of each of said sub-bands to each respective one of said sectors after said assigned second tones are used to communicate at least one symbol; and

a module for assigning at least a third tone for communication to each terminal within each of said sectors, each third tone assigned to each of said terminals being within said second sub-band assigned to the one of said sectors within which said each terminal is located.

13. The invention as defined in claim 11 or 12 wherein at least one of said sub-bands remains unassigned to any sector after execution of each of said assigning modules.

14. Apparatus for assigning tones in a cellular orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system, said system employing within a cell of said system

a plurality of directional antennas each oriented so as to divide said cell into a plurality of sectors, each of said sectors corresponding to one of said directional antennas, the apparatus comprising:

means for dividing a frequency spectrum available to said OFDM based spread spectrum multiple access wireless system into a plurality of sub-bands;
means for assigning a first respective one of each of said sub-bands to each respective one of said sectors;
means for assigning at least a first tone for communication to each terminal within each of said sectors, each first tone assigned to each of said terminals being within said first sub-band assigned to the one of said sectors within which said each terminal is located;
means for using said assigned first tones to communicate at least one symbol:
means for assigning at least a second tone for communication to each terminal within each of said sectors, each second tone assigned to each of said terminals being within said first sub-band assigned to the one of said sectors within which said each terminal is located;
means for using said assigned second tones to communicate at least one symbol;
means for assigning a second respective one of each of said sub-bands to each respective one of said sectors;
means for assigning at least a third tone for communication to each terminal within each of said sectors, each third tone assigned to each of said terminals being within said second sub-band assigned to the one of said sectors within which said each terminal is located.

15. The invention as defined in 14 wherein said first tone is used for communication first, subsequently said second tone is used for communication, and yet later than use of said second tone said third tone is used for communication.

16. The invention as defined in 14 further comprising:

means for using said assigned third tones to communicate at least one symbol;
means for assigning at least a fourth tone for communication to each terminal within each of said sectors, each fourth tone assigned to each of said terminals being within said second sub-band assigned to the one of said sectors within which said each terminal is located.

17. Apparatus for assigning tones in a cellular orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system, said system employing within a cell of said system a plurality of directional antennas each oriented so as to divide said cell into a plurality of sectors, each of said sectors corresponding to one of said directional antennas, the apparatus comprising:

means for dividing the frequency spectrum available to send OFDM based spread spectrum multiple access wireless system into a plurality of sub-bands;
means for assigning a first respective one of each of said sub-bands to each respective one of said sectors;
means for assigning at least a first tone for communication to each terminal within each of said sectors, each first tone assigned to each of said terminals being within said first sub-band assigned to the one of said sectors within which said each terminal is located;
means for using said assigned first tones to communicate a plurality of symbols;
means for assigning a second respective one of each of said sub-bands to each respective one of said sectors;
means for assigning at least a second tone for communication to each terminal within each of said sectors, each second tone assigned to each of said terminals being within said second sub-band assigned to the one of said sectors within which said each terminal is located.

18. The invention as defined in claim 14 or 17 wherein at least one of said sub-bands remains unassigned to any sector after assignments are made by each of said means for assigning.

19. A method for operating a cellular orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system, employing within a cell of said system a plurality of directional antennas each oriented so as to divide said cell into a plurality of sectors, each of said sectors corresponding to one of said directional antennas, the method comprising the steps of:

assigning to each of said sectors a sub-band from within a frequency spectrum available to said OFDM based spread spectrum multiple access wireless system;
using tones within said assigned sub-bands for communication with remote terminals within said sectors for at least two symbol periods;
assigning to each of said sectors a new one of said sub-bands; and
using tones within said new assigned sub-bands for communication with remote terminals within said sectors for at least one symbol period.

20. Apparatus for operating a cellular orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system, employing within a cell of said system a plurality of directional antennas each oriented so as to divide said cell into a plurality of sectors, each of said sectors corresponding to one of said directional antennas, the method comprising the steps of:

a tone assignment unit for assigning to each of said sectors a sub-band from within a frequency spectrum available to said OFDM based spread spectrum multiple access wireless system and for specifying particular tones within said assigned sub-bands for communication with terminals within said sectors for at least two symbol periods; and for further assigning to each of said sectors a new one of said sub-bands and for specifying tones within said new assigned sub-bands for communication with said terminals within said sectors for at least one symbol period; and
a data-to-tone applier for applying data destined for said terminals with at least one of said tones assigned by said tone assignment unit.

21. The invention as defined in claim 20 wherein said data-to-tone applier receivers data from an encoder.

22. The invention as defined in claim 20 wherein said data-to-tone applier applies said tones to which data has been applied to a cyclic prefix prepender.

23. The invention as defined in claim 20 further comprising a tone-to-data extractor which extracts data from received tones, said received tones being from said terminals, and wherein each terminal only transmits on a tone that is within said sub-band that is presently assigned to the sector in which said each mobile terminal is located.

24. A method for use in operating a cellular orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system terminal, in which a cell of said system employs a plurality of directional antennas each oriented so as to divide said cell into a plurality of sectors, each of said sectors corresponding to one of said directional antennas, the method comprising the steps of:

transmitting information from each terminal within a sector of said cell on one or more tones selected to be within a sub-band of a frequency spectrum available to said OFDM based spread spectrum multiple access wireless system that is presently assigned to said sector with which said terminals are located
changing which sub-band is assigned to said sector; and
repeating said transmitting step.

25. A method for use in operating a cellular orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system terminal, in which a cell of said system employs a plurality of directional antennas each oriented so as to divide said cell into a plurality of sectors, each of said sectors corresponding to one of said directional antennas, the method comprising the steps of:

receiving information from each terminal within a sector of said cell on one or more tones selected to be within a sub-band of a frequency spectrum available to said OFDM based spread spectrum multiple access wireless system that is presently assigned to said sector with which said terminals are located
changing which sub-band is assigned to said sector; and
repeating said receiving step.

FIG. 1

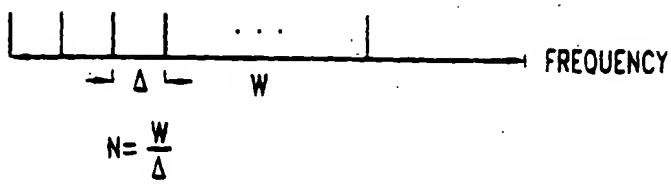


FIG. 2

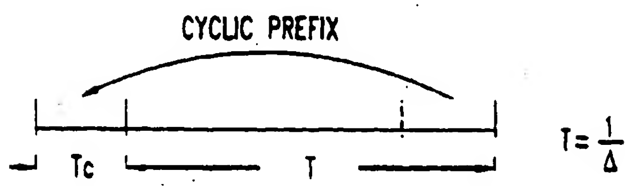


FIG. 3

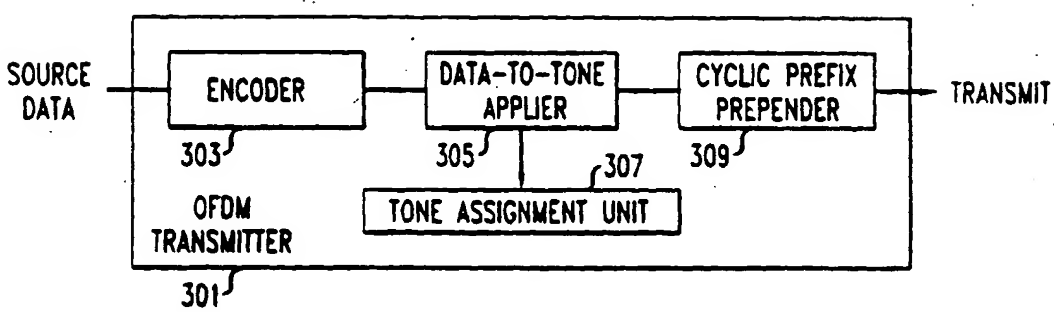


FIG. 4

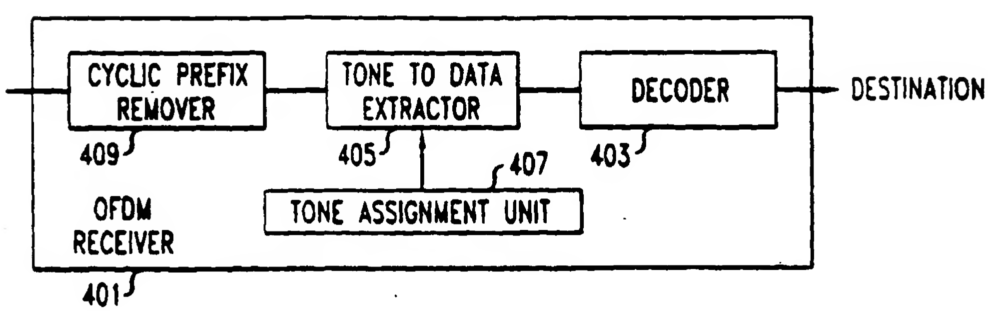


FIG. 5

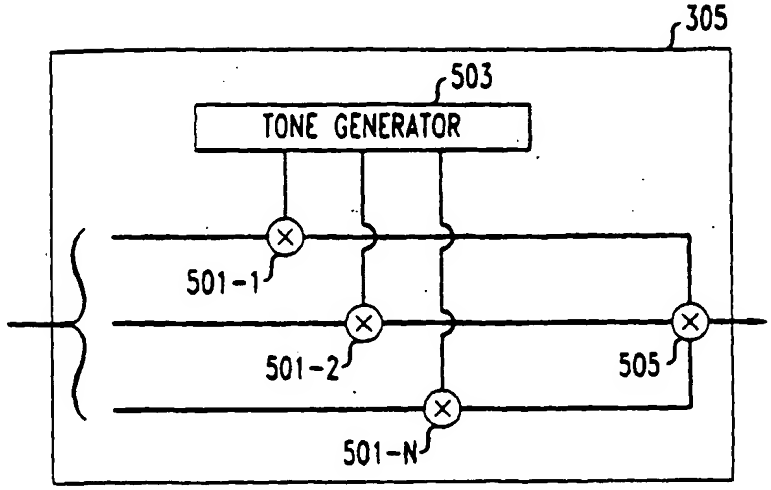


FIG. 6

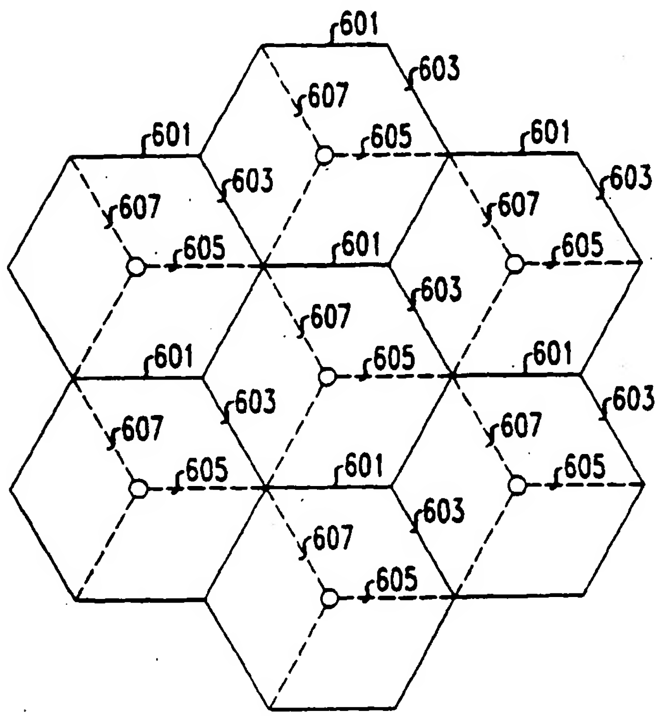


FIG. 7

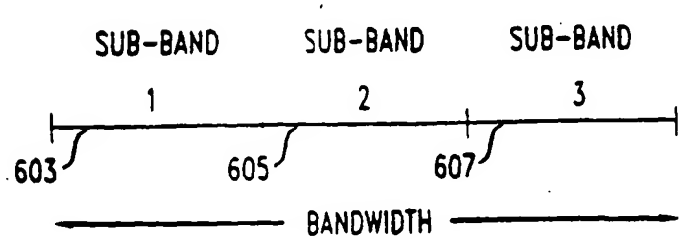


FIG. 8

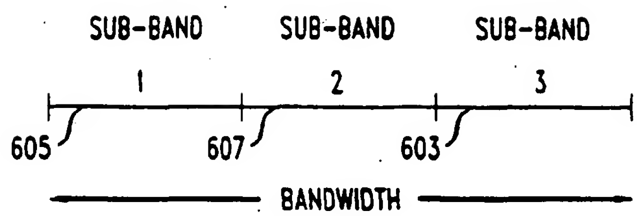
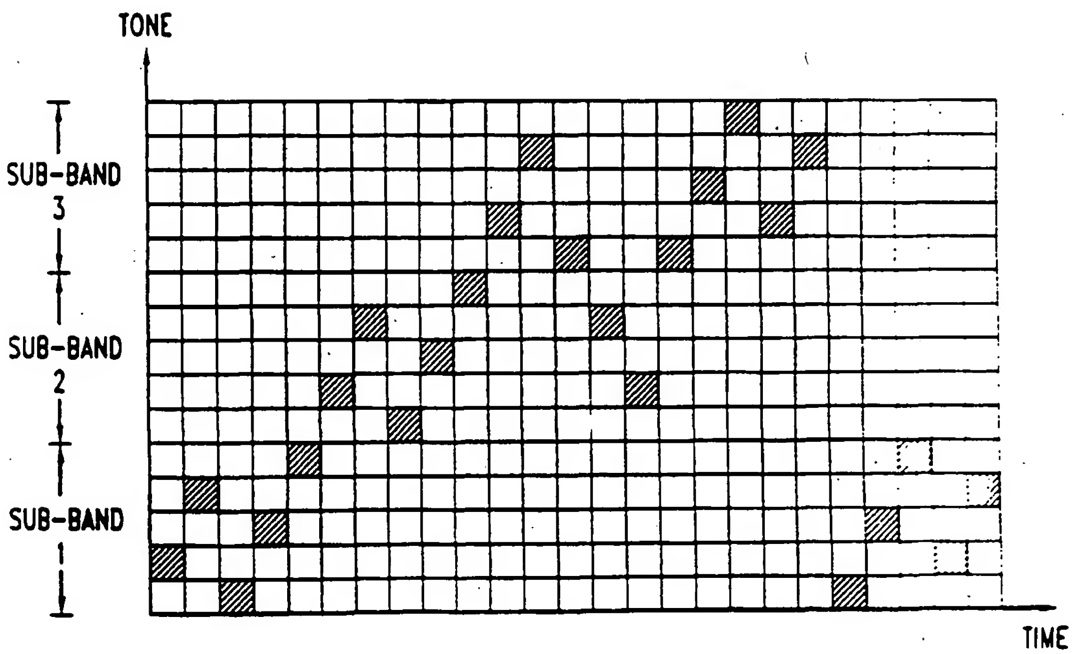

SUB-BAND
1
SUB-BAND
2
SUB-BAND
3
605
607
603
BANDWIDTH

FIG. 9


TONE
SUB-BAND
3
SUB-BAND
2
SUB-BAND
1
TIME

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 1577

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 5 410 538 A (ROCHE, WYNER) 25 April 1995 (1995-04-25) * column 2, line 38 - line 49 * * column 3, line 21 - line 33 * * column 4, line 29 *	1,8,11, 12,14, 17,19, 20,24,25	H04L5/02
X	WO 98 59450 A (MOTOROLA) 30 December 1998 (1998-12-30) * page 18, line 13 - page 19, line 6 * * page 19, line 21 - page 20, line 9 * * page 22, line 2 - line 11 * * page 22, line 25 - page 23, line 9 * * page 27, line 1 - line 6 * * page 35, line 18 - line 26 *	1,8,11, 12,14, 17,19, 20,24,25	
A	AUE, FETTWEIS: "Multi-carrier spread spectrum modulation with reduced dynamic range" IEEE VEHICULAR TECHNOLOGY CONFERENCE, 28 April 1996 (1996-04-28) - 4 May 1996 (1996-05-04), pages 914-917, XP000593107 New York, US ISBN: 0-7803-3158-3 * page 915, left-hand column, line 5 *	1,8,11, 12,14, 17,19, 20,24,25	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04L
A	EP 0 833 456 A (KOKUSAI DENSHIN DENWA CO LTD) 1 April 1998 (1998-04-01) * abstract *	1,8,11, 12,14, 17,19, 20,24,25	

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	4 August 2000	Scriven, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 1577

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A	IIDA, MARUBAYASHI: "Multi-tone combinatory frequency hopping system" IEEE INTERNATIONAL SYMPOSIUM ON SPREAD SPECTRUM TECHNIQUES AND APPLICATIONS , 22 - 25 September 1996, pages 893-897 , XP002144377 New York, US ISBN: 0-7803-3567-8 * abstract *	1,8,11, 12,14, 17,19, 20,24,25	

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04-08-2000

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